

INTEGRAL Spectrometer Analysis of GRB030227 & GRB030131

L. Moran^{*}, L. Hanlon^{*}, B. McBreen^{*}, R. Preece[†], Y. Kaneko[‡], O.R. Williams^{**}, K. Bennett^{**}, R. Marc Kippen[‡], A. Von Kienlin[§], V. Beckmann[¶], S. McBreen^{*} and J. French^{*}

^{*}*Department of Experimental Physics, University College Dublin, Ireland*

[†]*Department of Physics, University of Alabama at Huntsville, USA*

^{**}*Science Operations and Data Systems Division of ESA/ESTEC, SCI-SDG, NL-2200 AG Noordwijk, The Netherlands*

[‡]*Space and Remote Sensing Sciences, Los Alamos National Laboratory, USA*

[§]*Max-Planck-Institut für Extraterrestrische Physik, 85748 Garching, Germany*

[¶]*NASA Goddard Space Flight Center, University of Maryland Baltimore County, USA*

Abstract. The spectrometer SPI on board INTEGRAL is capable of high-resolution spectroscopic studies in the energy range 20 keV to 8 MeV for GRBs which occur within the fully coded field of view (16° corner to corner). Six GRBs occurred within the SPI field of view between October 2002 and November 2003. We present results of the analysis of the first two GRBs detected by SPI after the payload performance and verification phase of INTEGRAL.

INTRODUCTION

On October 17th 2002, ESA's gamma-ray observatory INTEGRAL was successfully launched from the Baïkonur Cosmodrome in Kazakhstan. INTEGRAL has a burst alert system (IBAS) which carries out rapid localisations for gamma-ray bursts (GRBs) incident on the IBIS detector. These co-ordinates are then distributed, allowing for fast follow up observations at other wavelengths [1]. The main instruments IBIS and SPI also contribute greatly to INTEGRAL's GRB capabilities. IBIS is a high resolution imager [2] with angular resolution of 12 arcminutes for sources within its 9° × 9° fully coded field of view and broadband spectral capabilities. SPI is optimised for spectroscopic study of gamma-ray sources, with some imaging capabilities. IBIS and SPI are complemented by two smaller instruments, JEM-X and OMC, which monitor gamma-ray sources at x-ray and optical wavelengths.

SPI consists of 19 high purity Germanium detectors actively cooled to a temperature of ~ 85 K to provide an energy resolution FWHM of 2.5 keV at 1 MeV [3] in the range 20 keV-8 MeV. SPI's imaging capabilities are due to a coded mask comprising of 127 tungsten elements, with a thickness of 30 mm, placed at a distance of ~ 1.7 m from the detection plane, providing an angular resolution of 2.8°. The good angular resolution combined with excellent spectral resolution make SPI an ideal instrument for spectral studies of the prompt emission of GRBs.

GRBs, first detected over 35 years ago, are an intriguing phenomenon and remain at the forefront of research in astrophysics. The discovery by BeppoSAX of afterglows in

the x-ray [4] and subsequent discoveries at optical [5] and radio [6] wavelengths have led to redshift measurements [7] for ~ 40 bursts ranging from $z = 0.168 - 4.5$. A theory of gamma-ray bursts must provide a mechanism capable of a non-thermal energy output of the order of $10^{52} - 10^{54}$ ergs by compact sources at cosmological distances.

With a large detector area of approximately 500 cm^2 and its high spectral resolution, SPI can address the long-standing controversy over the existence of short-lived spectral features in GRB spectra, previously searched for with varying degrees of success [8, 9]. A confirmation of line features and details of specific spectral features could contribute to the debate on the connection between GRBs and core-collapse supernovae [10]. In addition, the broad energy coverage of SPI (20 keV-8 MeV) is well suited to constrain the spectral shape, both below and above the energy at which the GRB power output is typically peaked ($\sim 250 \text{ keV}$). Study of the spectral shape of the prompt emission of a GRB at the onset of the afterglow from SPI data could reveal the activity of the central engine that leads to the production of an afterglow. At the high energy end, there may exist a hard spectral upturn as recently found by González et al. (2003) in archival CGRO data of GRB941017.

SPI DATA ANALYSIS OF GRBS

A standard SPI pointing has a duration of ~ 35 minutes. In this Science Window (ScW) the numbers of single, double and higher multiplicity events striking each detector are recorded according to the energy (16384 channels). Photon by photon information, which contains details of the detector struck, the energy deposited and the exact time, is available for multiple events and all events analysed by the Pulse Shape Discriminator (PSD), about 10% of the total. The standard SPI pipeline is designed to process sets of ScWs [12], whereas a GRB lasts only a fraction of this duration. Therefore, a modified analysis procedure (see Fig. 1) is used in which the start and end times and the best known position of the GRB are manually inserted.

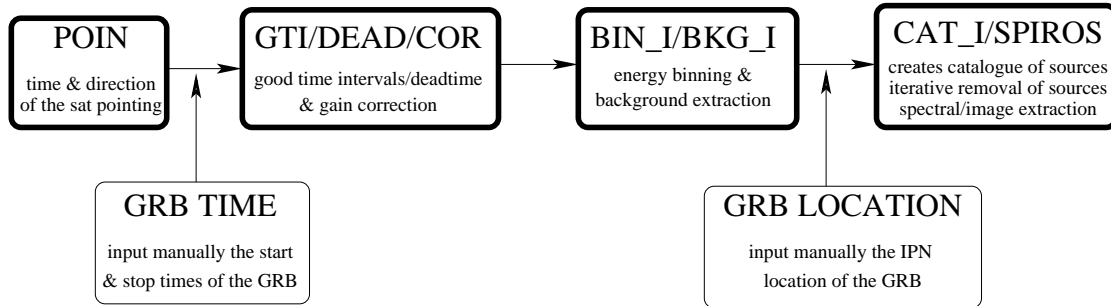


FIGURE 1. Flow chart of the SPI instrument specific software pipeline, including the additional steps necessary for GRB analysis.

RESULTS

GRB030131 At 07:39:00 UT on January 31st 2003, SPI detected a gamma-ray burst of duration ~ 60 s, the first since commencing full operational status. The corrected INTEGRAL position of the burst was given in *GCN 1847* as RA 202.13° and DEC

30.68° with a 5' radius error. The analysis of GRB030131 is complicated by the fact that 10 s after the GRB onset, the spacecraft started slewing and the remaining 50 s of the burst, including the brightest portion, occurred during this manoeuvre.

There are two main problems which arise when a SPI observation takes place during a satellite slew. The first is that not all types of events are recorded during a slew. To facilitate compression and transmission of the data from the preceding steady pointing, only multiple events and those single events analysed by the PSD are downlinked, together with the technical- and science-housekeeping data, with the loss of $\sim 90\%$ of the single events.

The second complication is that to utilise the analysis procedure developed, the pointing direction of the instrument and details of the slew must be established and manually inserted. In particular, the RA and DEC of the satellite's orientation need to be chosen to reflect the motion of the spacecraft. As burst emission is evident for one third of the length of the slew, the co-ordinates of the SPI field of view were deemed to lie one sixth of the angular distance from the preceding steady pointing to the subsequent one.

Spectral analysis was not possible with the limited telemetry received, but using the imaging capabilities of SPI the burst was located with a detection significance of 3.6σ . The first row in *Table 1* gives the results obtained using the modified pipeline for the brightest 10 s of the burst.

TABLE 1. Results for the brightest 10 s of GRB030131.

RA	DEC	σ	Flux(ph/cm ² /s)	Energyrange(keV)
200.650	30.210	3.6	0.86 ± 0.24	20-500
201.967	31.117	7.0	-	20-8000

Taking into account the SPI localisation precision of 2.8° , the SPI and IBIS locations are in agreement. The flux obtained is also consistent with that derived from IBIS data [13]. The second row in *Table 1* shows the results of analysis performed using the science-housekeeping data. This method does not require an input location and yet still locates a source consistent with the GRB location with a significance of 7σ .

GRB030227 began at 08:42:04 UT on 27th February 2003 and had a duration of 18 s. Though a weak burst [14], SPI images the burst with a detection significance of 7.5σ and location in agreement with IBIS. A power law model fit to GRB030227 using XSPEC yields a photon index of 1.95 ± 0.17 . Another fit using the same model in RMFIT [15] yields a photon index of 1.96 ± 0.18 , where the data have been rebinned to increase the S/N (see Fig. 2). In both cases there is very good agreement between the results of SPI and the IBIS analysis in Mereghetti et al. (2003). In the energy range 20-200 keV the flux obtained for the burst is:

$$F_{20-200\text{keV}} = 5.5^{+5.1}_{-2.7} \text{ erg/cm}^2/\text{s}.$$

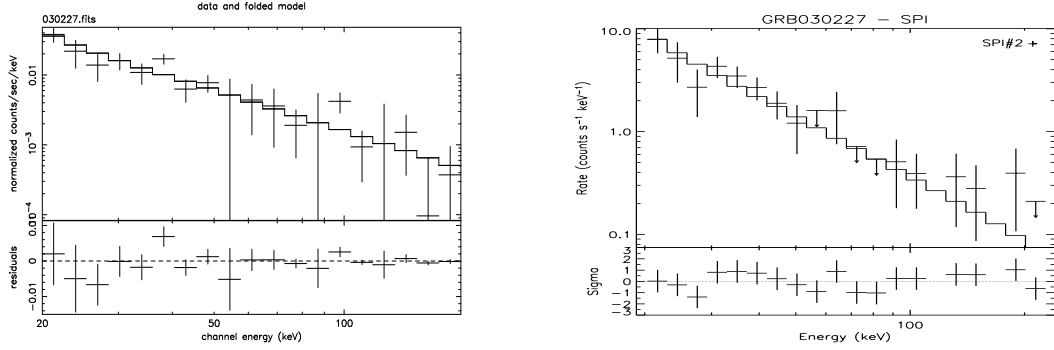


FIGURE 2. A power law model is fit to GRB030227 using *left*: XSPEC, yielding a photon index of 1.95 ± 0.17 and *right*: RMFIT, yielding a photon index of 1.96 ± 0.18 .

CONCLUSIONS

GRB030131 was the first GRB in the FOV of the main instruments after the performance and verification phase of the satellite. The analysis of this burst shows the capabilities of the SPI instrument during a satellite slew, a frequent manoeuvre ($\sim 10\%$ of the time) due to the dither pattern employed by INTEGRAL. With limited telemetry it was still possible to image the burst and obtain a location and a flux. Although it was not feasible to carry out spectral analysis in this case, the imaging capability of SPI allows for cross calibration with IBIS. For GRB030227, though a very faint burst, a spectrum can be extracted in SPIROS and used to fit models in both XSPEC and RMFIT, obtaining a photon index and a flux in good agreement with previous work [14]. Therefore, SPI has demonstrated that when a burst of sufficient intensity is observed it will be possible to study the prompt emission of a GRB with the sensitivity necessary to determine the spectral evolution, identify hard spectral components and constrain models.

REFERENCES

1. Mereghetti, S., et al., “Real time localisation of Gamma Ray Bursts with INTEGRAL,” in *Advanced Spectral Resolution*, Proceedings of the 34th COSPAR Scientific Assembly, Houston, 2002.
2. Ubertini, P., et al., *A&A*, **411**, L131–139 (2003).
3. Knödsleder, J., and Roques, J.-P., “SPI Science Prospects,” in *The Gamma-Ray Universe*, Proceedings of the XXII Moriond Astrophysics Meeting, Les Arcs, 2002.
4. Costa, E., et al., *Nature*, **387**, 783–785 (1997), [astro-ph/9706065].
5. van Paradijs, J., et al., *Nature*, **386**, 686–689 (1997).
6. Frail, D., et al., *Nature*, **389**, 261–263 (1997).
7. Metzger, M., *Nature*, **387**, 879–880 (1997).
8. Murakami, T., et al., *Nature*, **335** (1988).
9. Briggs, M., et al., “BATSE Evidence for GRB Spectral Features,” in *Gamma-Ray Bursts*, edited by R. P. T. K. C. Meegan, Proceedings of the 4th Huntsville Symposium 428, AIP, New York, 1997.
10. Hjorth, J., et al., *Nature*, **423**, 847–850 (2003), [astro-ph/0306347].
11. González, M., et al., *Nature*, **424**, 749–751 (2003).
12. Courvoisier, T.-L., et al., *A&A*, **411**, L53–57 (2003), [astro-ph/0308047].
13. Götz, D., et al., *A&A*, **409**, 831–834 (2003), [astro-ph/0307406].
14. Mereghetti, S., et al., *ApJ Letters*, **590**, 73–78 (2003), [astro-ph/0304477].
15. Preece, R., et al., *ApJSS*, **126**, 19–36 (2000), [astro-ph/9908119].